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U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

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**TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371**

US57.0357-WO

U.S. APPLICATION NO (If known, see 37 CFR 1.5)

10/088752

INTERNATIONAL APPLICATION NO.

PCT/GB00/04128

INTERNATIONAL FILING DATE

26 October 2000 (26.10.00)

PRIORITY DATE CLAIMED

27 October 1999 (27.10.99)

TITLE OF INVENTION DOWNHOLE DEPOSITION MONITORING SYSTEM

APPLICANT(S) FOR DO/EO/US

SCHLUMBERGER TECHNOLOGY CORPORATION

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International application as filed (35 U.S.C. 371(c)(2))
 - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
 - b. ☒ has been communicated by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
 - a. ☐ is attached hereto.
 - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
 - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ have been communicated by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☐ A **FIRST** preliminary amendment.
14. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821-1.825
18. ☒ A second copy of the published international application under 35 U.S.C. 154(d)(4). (**WO 01/31328 A1**)
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information:
- **Form PCT/IB/308 Notice Informing the Applicant of the Communication of the International Application to the Designated Offices**

U.S. APPLICATION NO (if known, see 37 CFR 1.5) <div style="font-size: 1.5em; font-weight: bold;">10/088752</div>		INTERNATIONAL APPLICATION NO <div style="font-weight: bold;">PCT/GB00/04128</div>		ATTORNEY'S DOCKET NUMBER <div style="font-weight: bold;">US57.0357-WO</div>	
21. <input checked="" type="checkbox"/> The following fees are submitted: BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)): Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO and International Search Report not prepared by the EPO or JPO \$1040.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO..... \$890.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO .. \$740.00 International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4)..... \$710.00 International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4)..... \$100.00 <div style="text-align: center;">ENTER APPROPRIATE BASIC FEE AMOUNT =</div>				CALCULATIONS PTO USE ONLY	
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input checked="" type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$890.00 \$130.00	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	25 - 20 =	5	x \$18.00	\$90.00	
Independent claims	2 - 3 =	0	x \$84.00	\$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ \$280.00	\$	
TOTAL OF ABOVE CALCULATIONS =				\$1110.00	
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				\$	
SUBTOTAL =				\$	
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TOTAL NATIONAL FEE =				\$1110.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property +				\$	
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NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.					
SEND ALL CORRESPONDENCE TO: Intellectual Property Law Department Schlumberger Doll Research 36 Old Quarry Road Ridgefield, CT 06877-4108			<div style="text-align: center;"> SIGNATURE </div> <div style="text-align: center;"> William B. Batzer NAME </div> <div style="text-align: center;"> <div style="border-bottom: 1px solid black; display: inline-block; width: 100px;"></div> 37,088 REGISTRATION NUMBER </div>		

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Downhole Deposition Monitoring System

This invention relates to apparatus and methods for monitoring solid deposits of material in a wellbore and operating downhole sensors and other wellbore equipment. Particularly, the invention relates to such apparatus and methods for sensing and removing solid deposits in hydrocarbon wells.

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BACKGROUND OF THE INVENTION

The formation of both organic and inorganic deposits in the near wellbore region of producing formations and on the tubing of a producing hydrocarbon well can be a major and costly problem.

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See, e.g. Allen, T.O. and Roberts, A.P., *Production Operations*, Vol. 2, 2nd edition, pp. 11-19 and 171-181, OGCI, Tulsa, Ok.

(1982);

Cowan, J.C and Weintritt, D.J., *Water-formed Scale*

Deposits,

Gulf Publishing Co., Houston (1976). The deposits can

seriously

impede the productivity of wells by reducing the near

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wellbore permeability of producing formations and progressively restrict the diameter of the tubing.

The formation of inorganic deposits, or scale, is caused by the precipitation of inorganic salts from produced water. Calcium

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carbonate scale is usually formed by the change in the pressure and temperature of the produced water in the near wellbore and

in the production tubing. Barium, strontium and calcium sulphate

scales are usually formed by the mixing of formation water and

seawater injected into producing wells; the high concentration

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of sulphate in seawater mixes with the high concentrations of

divalent cations in formation waters with the resulting

precipitation of the sulphate salts. The formation of scale may

be partly prevented by water shut-off treatments and the use of

scale inhibitors. Once formed, scale can be removed only with

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some difficulty; calcium carbonate scale can be dissolved by

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mineral acids and barite scale can be removed by milling or scale dissolvers such as EDTA. See, e.g. Putnis, A, Putnis, C.V. and Paul, J.M., "The efficiency of a DTPA-based solvent in the dissolution of barium sulfate scale deposits", *SPE International Symp. Oilfield Chemistry*, San Antonio, Texas, February 1995, SPE 29094. In extreme cases the production tubing must be removed and replaced, although the presence of radioactive scale (due to the presence of radium salts) can make scale disposal an environmental issue.

The production of hydrocarbons frequently causes the precipitation of organic precipitates such as paraffin waxes and asphaltenes. These organic precipitates are caused by changes in the pressure and temperature of the produced fluids in the near wellbore. The precipitates can be removed with solvent washes, although the disposal of the solvent after cleaning represents an increasing environmental problem.

The solubility of various inorganic and organic species can be predicted from thermodynamic models of the electrolyte solutions or hydrocarbons. See, e.g. Jasinski, R, Taylor, K. and Fletcher, P., "Calcite scaling - North Sea HTHP wells", *SPE Symp. Oilfield Scale*, Aberdeen, January 1999; Calange, S., Ruffier-Meray, V. and Behar, E., "Onset crystallization temperature and deposit amount for waxy crudes: experimental determination and thermodynamic modelling", *SPE International Symp. Oilfield Chemistry*, Houston, Texas, February 1997, SPE 37239. However, thermodynamic models are essentially equilibrium models and they cannot predict any details of the precipitation process such as the location of precipitation, the rate of precipitation or the degree of supersaturation that the fluid can tolerate.

Several patents and papers have described both acoustic and non-acoustic methods for sensing the formation of scale in producing

hydrocarbon wells and similar environments. An acoustic method for measuring the thickness of metal oxide corrosion products on the inside of boiler tubes has been described. See Lester, S.R., "High frequency ultrasonic technique for measuring oxide
5 scale on the inner surface of boiler tubes", *US Patent* 4,669,310, June 2, 1987. The thickness of oxide scale is determined by the time of flight of an acoustic pulse applied from the external surface of the pipe. The frequency of the acoustic pulse was 50 MHz, which enabled a scale thickness of
10 approximately 0.1 mm to be detected. The use of an automated ultrasonic inspection system for determining the thickness of scale formation which has formed on the inside of heat transfer tubes in boilers has been described. See Okabe, Y., Iwamoto, K., Torichigai, M., Kaneko, S., Ichinari, J. and Koizumi, K.,
15 "Automated ultrasonic examination system for heat transfer tubes in a boiler", *US Patent* 4,872,347, October 10, 1989. A rotating transducer was inserted into the tubes and their diameter as a function of location determined by the reflection of sound from the scale-water interface. An acoustic wireline logging tool,
20 Schlumberger's Cement Evaluation Tool (CET), has been used to determine the accumulation of scale on the casing of geothermal wells. See, *US Patent* No 5,072,388, to O'Sullivan et al. The interfaces between the scale and wellbore fluid and the scale and the casing are determined by the transit time of the
25 acoustic waves, which have a frequency of approximately 0.5 MHz. *US Patent* 5,092,176 disclosed a method for determining the thickness of scale on the inside of a water pipe by the attenuation of acoustic energy emitted and received by a transducer on the outside of the pipe. The optimum frequency
30 range for the ultrasound was observed to be 3-7 MHz. For example, measurements made using ultrasound below a frequency of 3 MHz gave poor sensitivity to scale thickness and beam spreading was observed to be a problem. An acoustic method of identifying scale types and scale thickness in oil pipelines
35 using the attenuation in the reflected acoustic signal from a

tool that is moved through the inside of the pipe has been described. See, Gunarathne, G.P.P. and Keatch, R.W., "Novel techniques for monitoring and enhancing dissolution of mineral deposits in petroleum pipelines", *SPE Offshore Europe Conference*, Aberdeen, Sept. 1995, SPE 30418 (hereinafter "Gunarathne"); Gunarathne, G.P.P. and Keatch, R.W., "Novel techniques for monitoring and enhancing dissolution of mineral deposits in petroleum pipelines", *Ultrasonics*, **34**, 411-419 (1996) (hereinafter "Gunarathne and Keatch"). The frequency of the ultrasound used was in the range 3.5-5.0 MHz, which allowed the thickness of barium sulphate scale on steel to be measured to an accuracy of ± 0.5 mm.

US Patent 5,661,233 (hereinafter "Spates et al.") disclosed several acoustic-wave devices for determining the deposition of organic precipitates, such as paraffin wax, on to a sensing surface immersed in a petroleum-based fluid. The acoustic measurements were made with devices using various acoustic modes: surface acoustic waves and thickness shear, acoustic plate and flexural plate modes. The devices measured changes in the damping voltage and resonant frequency of the device as the wax precipitate formed, although no details were disclosed regarding the operating frequencies of the acoustic devices or the acoustic power they generated. Spates et al. discussed periodic cleaning of the sensing surface of the acoustic device by heating the surface to melt the paraffin wax. However, the use of acoustic energy to clean the organic precipitates from the acoustic sensor was not disclosed or suggested. Several applications of the measurement of wax accumulation were described, including location of acoustic devices on the sea floor to monitor the production of hydrocarbon from oil wells and guide well treatments. The application of a quartz microbalance to measure simultaneously mass loading and liquid properties has been described. See, US Patent 5,201,215; Martin, S.J., Granstaff, V.E. and Frye, G.C., "Characterisation

The use of a thickness-shear mode resonator to monitor the formation of barium sulphate in samples of produced water collected at the well head has been described. See, Emmons, D.H. and Jordan, M.M., "The development of near-real time monitoring of scale deposition", *SPE Oilfield Scale Symposium*, Aberdeen, 27-28 Jan., 1999 (hereinafter "Emmons and Jordan"). The resonator was immersed in a fixed volume of produced water and known amounts of soluble barium ions were added to precipitate barium sulphate scale. The resonator detected the

formation of scale on its sensing surface by a decrease in resonant frequency. The amount of barium added before scale formation was detected by the resonator gave an indication of the level of inhibition in the produced water. Emmons and Jordan
5 argued that the formation of scale by small additions of barium ions indicated the produced water was close to scaling and treatment of the well by a suitable scale inhibitor was required. Note that this method of monitoring scale formation is not an *in situ* method and does not measure the spontaneous
10 formation of scale under downhole conditions of temperature, pressure, composition and flow. In addition, the resonator was not able to clean the scale from its sensing surface. A quartz crystal microbalance to monitor the formation of calcium carbonate scale under laboratory conditions has been described.
15 See, Gabrielli, C., Keddam, M., Khalil, A., Maurin, G., Perrot, H., Rosset, R. and Zidoune, M., "Quartz crystal microbalance investigation of electrochemical calcium carbonate scaling", *J. Electrochem. Soc.*, **145**, 2386-2395 (1998). The resonant frequency of the microbalance was 6 MHz and calcium carbonate
20 deposition rates of 200-400 $\mu\text{g}/\text{cm}^2$ per hour were measured. The calcium carbonate scale was observed to be the mineral calcite, which, with an assumed density of 2.71 g/cm^3 , gave deposits of 0.7-1.5 μm in thickness. The rate of scale accumulation measured by the quartz microbalance was compared with a standard
25 electrochemical scale monitor that measured the redox current passing through an electrode as water was reduced. The decline in redox current gave an indirect measure of the decrease in the surface area of the electrode as it was covered with scale and was observed to be less sensitive to scale formation than the
30 quartz crystal microbalance. The use of a piezoelectric quartz crystal to monitor the fouling of surfaces in a water cooling tower by inorganic scale and bacterial growth at ambient conditions has been described. See, Nohata, Y. and Taguchi, H., "An ultrasensitive fouling monitoring system for cooling
35 towers", *Materials Performance*, **34**, 43-46 (1995) (hereinafter

"Nohata and Taguchi"). Although Nohata and Taguchi did not specifically disclose the operating frequency of the quartz crystal, a value of about 5 MHz can be deduced from the measured accumulation rates of 1-20 $\mu\text{g}/\text{cm}^2$ per day.

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The use of a tuning fork for measuring the deposition of scale in a surface process system has been disclosed. See, US Patent 5,969,235. The accumulation of scale on the tines of the tuning fork causes a shift in the characteristic vibrating frequency of the tuning fork as measured by a suitable electronic device, such as a piezoelectric cell. The change in vibrating frequency of the tuning fork, indicating the deposition of scale, was used to control the addition of scale inhibitor to the process stream.

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Non-acoustic scale sensing techniques have also been reported. A method of determining the accumulation of scale in petroleum pipelines using a heat transfer sensor has been described. See, US Patent 4,718,774. The scale formed on the external wall of the sensor impeded the loss of heat from a heating element in the sensor to the fluid flowing in the pipeline. The decrease in heat flow was measured by means of a temperature sensor. A wellbore scale monitor that measured the radioactivity of the radium salts precipitated with other alkaline earth metal salts has been described. See, US Patent 4,856,584 (hereinafter "Sneider"). Sneider discloses the use of measurements of scale radioactivity to indicate when and where the placement of scale inhibitor is required. Another scale monitoring technique is disclosed in US Patent 5,038,033; the radioactivity of the scale was detected by a wireline gamma ray detector, correcting for the natural gamma radiation emitted from the surrounding rock formations.

Accurately measured pressure drops over various sections of a reinjection pipeline in a geothermal power plant has been used

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A number of published reports have described the application of sonic energy for cleaning producing oil wells and equipment in similar industrial processes. A method of cleaning downhole deposits, such as tar, from producing formations and production tubing was disclosed in US Patent 3,970,146. However, no details were given of the power or frequency of the sound used for wellbore cleaning. A low frequency (20-100 Hz) vibrating device for cleaning deposits on the walls of casing and tubing and in

formations and gravel packs was disclosed in US Patent 4,280,557. The vibrations were generated in the device by an orbiting mass on an unbalanced rotor, which, in turn, produced a whirling vibratory pressure of large amplitude in the fluid in the annulus. US Patent 4,320,528 disclosed a method of removing iron oxide corrosion products and other scaling deposits from the pipes of steam generators using a combination of high power sound and a high-temperature solvent (e.g., sodium EDTA, citric acid and a corrosion inhibitor). The acoustic transducers operated in the frequency range 2-200 kHz and generated an output acoustic power greater than 0.2 W/cm², a value which is above the cavitation threshold of aerated water at ambient pressure and temperature. See, Esche, R., "Untersuchung der Schwingungskavitation in Flüssigkeiten", *Acustica*, 2, AB208-218 (1952); Mason, T.J. and Lorimer, J.P., *Sonochemistry: Theory, Applications and Uses of Ultrasound in Chemistry*, p 31, Ellis Horwood, Chichester, UK (1988). The transducers were located permanently on the outside of the heat exchanger tubes. US Patent 4,444,146 disclosed an ultrasonic method to clean the fouled surfaces of submerged structures, such as the hulls of ships. The ultrasonic cleaner consisted of two ultrasonic transducers focussed on a small area of surface to be cleaned. The transducers operated at slightly different frequencies, typically in the range 180-210 kHz; no details were disclosed on the acoustic power required to clean the fouled surfaces. UK Patent Application 2 165 330 A (hereinafter "D'Arcy et al.") disclosed a method of cleaning underwater structures to depths of up to 1000 metres using focussed ultrasound in the frequency range 40-100 kHz. The ultrasound was generated and focussed using an array of transducers located on the concave surface of a spherical cap. The density of acoustic power at the focal point of the array of transducers was stated to be about 500 W/cm², a value that is approximately 3 orders of magnitude above the cavitation threshold of water at ambient pressure. D'Arcy et al. suggested the high power acoustic array could be used to

15 It has been shown that ultrasound applied at a frequency of 10 kHz could remove asphaltene deposits from a sand pack saturated with both water and kerosene at ambient pressure. See, Gollapdi, U.K., Bang, S.S. and Islam, M.R., "Ultrasonic treatment for removal of asphaltene deposits during petroleum
20 production", *SPE International Conf. Formation Damage Control*, Lafayette, Louisiana, February 1994, SPE 27377. Although the acoustic power applied to the sand packs during cleaning was not measured, the ultrasonic transducer could generate a maximum output acoustical power of 250 W. The authors discussed the role
25 of acoustic cavitation in the cleaning process and acoustic cavitation was undoubtedly achieved at the power settings reported. The asphaltene deposits were observed to be removed significantly more efficiently by the ultrasound in kerosene than in water. It has been demonstrated under laboratory
30 conditions that the damage caused to permeable formation by the invasion of clay particles from drilling fluids can be partially removed by the application of high power ultrasound. See, Venkitaraman, A., Roberts, P.M. and Sharma. M.M., "Ultrasonic removal of near-wellbore damage caused by fines and mud solids",
35 *SPE Drilling & Completions*, 10, 193-197 (1995). Two ultrasonic

transducers were used; one was a high power ultrasonic horn operating at a frequency of 20 kHz with an output power of up to 250 W and the other was a low power transducer operating over frequency range 10-100 kHz. The same authors subsequently
5 evaluated the application of high power ultrasound under laboratory conditions for the removal of organic deposits and formation damage caused by the invasion of drilling fluid filtrate containing water-soluble polymers. See, Roberts, P.M., Venkitaraman, A. and Sharma, M.M., "Ultrasonic removal of
10 organic deposits and polymer induced formation damage", *SPE Formation Damage Control Symp.*, Lafayette, Louisiana, February 1996, SPE 31129. Using the same ultrasonic transducers, it was demonstrated that polymer-induced formation damage was considerably more difficult to remove than the damage caused by
15 clay fines. However, formation damage resulting from the precipitation of wax in the test core samples could be removed by sonication when the core samples were soaked in a suitable solvent.

20 US Patent 5,595,243 disclosed the use of a general purpose acoustic cleaning tool for improving the near wellbore permeability of producing formations by redissolving or resuspending restricting materials. The cleaning tool was reported to generate acoustic power densities of up to 2 W/cm²,
25 which is above the cavitation threshold for water at ambient temperature and pressure. See, US Patent 4,280,557. The tool, which consisted of an array of air-backed high power acoustic transducers of the type described by Widener, was designed to be deployed into the well on a wireline cable. See, Widener, M.W.,
30 "The development of high-efficiency narrow-band transducers and arrays", *J. Acoust. Soc. Amer.*, **67**, 1051-7 (1980); Widener, M.W., "The development of a deep submergence air-backed transducer", *J. Acoust. Soc. Amer.*, **80**, 1852-3 (1986). The transducers described by Widener would be expected to operate in
35 the frequency range 10-100 kHz. US Patent 5,676,213 disclosed the

use of high power ultrasound to remove the filter cake formed by the drilling fluid during the drilling of a well in order to measure the pressure in permeable formations. The high power ultrasound was generated by a focussing transducer operating in the frequency range 100-500 kHz and capable of operating at a peak input power of up to 1 kW. US Patent 5,727,628 disclosed an ultrasonic tool for cleaning producing wells. The wireline-deployable tool consisted of an array of magnetostrictive transducers operating in the frequency range 18-25 kHz (preferably at 20 kHz) and emitting an acoustic power density in the range 8-12 W/cm². The tool was also equipped with a pump to remove the debris of the fouling deposits disaggregated by the ultrasonic tool. US Patent 5,735,226 disclosed a method to prevent the fouling of ships and other marine structures by the use of ultrasound over the frequency range 20-60 kHz. One demonstration of the technique was the location of a number of ultrasonic transducers on the hull of a ship over a period of 4 months. Over this time period the transducers, which were powered intermittently, gave effective relief from marine fouling. US Patent 5,735,226 revealed no details of the power consumption of the transducers, but one embodiment of the invention consisted of the array being powered by a 9 volt battery. US Patent 5,889,209 disclosed the use of high power ultrasound to prevent biofouling of chemical sensors used in aquatic environments. The ultrasound was generated by a transducer operating in the frequency range 10-100 kHz and yielding a sufficient power density (> 0.1-1 W/cm²) to drive acoustic cavitation. US Patent 5,889,209 disclosed the use of the acoustic cleaning technique to maintain the performance of a dissolved oxygen sensor located in microbiologically active water for seven days. The transducer was located over the range 4-10 mm from the active membrane of the oxygen sensor and activated for a time period of 6-90 seconds over a time interval of 5-120 minutes.

In conclusion, there appears to be no prior art that teaches or suggests either an acoustic scale sensor or an acoustic cleaning device located permanently or quasi-permanently in a well producing hydrocarbons. There appears to be no prior art of teaches or suggests the concept of a sensor for hydrocarbon wells to monitor the formation of inorganic or organic scales, biofouling or corrosion and initiate a cleaning action. Additionally, there appears to be no prior art that teaches or suggests an on-line deposits monitoring and cleaning device located on the surface facilities of a producing oil well using an ultrasonic transducer operating in its longitudinal mode and coupled to the produced fluids using a coupling material, such as an acoustic horn, to which the deposits adhere.

SUMMARY OF THE INVENTION

5 It is an object of this invention to describe an apparatus that can be placed at various locations to monitor the deposition of scale and other deposits and preferably to remove such deposits.

According to the invention a deposit monitoring apparatus
10 located in a hydrocarbon wellbore is provided comprising: an acoustic device adapted to operate in a resonance mode including a monitoring surface directly exposed to fluids in a hydrocarbon wellbore, wherein the deposition of material on the monitoring surface is monitored by measuring a change in resonance
15 frequency of the acoustic device; and a power supply adapted to supply said monitor with electrical energy.

The acoustic device is preferably mounted either permanently or quasi-permanently in the wellbore.

20 According to another aspect of the invention, a deposit monitoring apparatus located in a hydrocarbon wellbore is provided, comprising: a deposit monitor adapted to measure deposition of material on a monitoring surface that is directly
25 exposed to fluids in the hydrocarbon wellbore; a power supply adapted to supply said monitor with electrical energy; and a deposit removal system in communication with the deposit monitor adapted to at least partially remove the deposition from the monitoring surface, the deposit removal system being in a
30 control loop with said deposit monitor.

In a preferred embodiment the deposit monitor is a high power ultrasonic transducer, operating in a longitudinal mode, coupled to the fluids produced from the well by a solid coupling device,
35 such as an acoustic horn, for measuring the deposition of the

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the deposits on the surrounding material are accurately measured.

At least the tip of the horn is directly exposed to the wellbore fluid causing the deposition.

The transducer is able to detect inorganic deposits or scales, such as barium sulphate or calcium and organic deposits, such as waxes, at a thickness of approximately 100 μm .

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Scales can be removed from the transducer by operation at high power; the transducer is therefore able both to detect and clean deposits. The ultrasonic transducer is also able to clean scale from the surfaces of other components located at various positions in producing hydrocarbon wells, such as those made of glass, metal or plastics. The acoustic transducers can be permanently located in producing hydrocarbon wells and indicate the location and rate of scale deposition. The measurement of scale deposition can be used to direct scale treatment procedures, such as the placement of inhibitors or the application of scale dissolvers, and to warn of scale accumulation on critical downhole production equipment, such as chokes, sliding sleeves and separators. The acoustic scale sensor can also be used to determine the effectiveness of any treatment to remove scale or other wellbore deposits.

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The control loop comprises either be a suitably programmed microprocessor or computer executing pre-programmed tasks. Or, it could include visual display units allowing a human operator to make decisions based on the measurements provided by the deposit monitor.

Permanently or quasi-permanently installed in a wellbore or below the surface of the Earth refers to installation that are

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FIG. 7 illustrates a downhole installation in accordance with the invention;

5 FIG. 8 illustrates a sensor installation with self-cleaning equipment in accordance with the invention;

10 FIGs. 9A,B illustrate further sensor installations with self-cleaning equipment in accordance with the invention; and

15 FIG. 10 shows a schematic sensor adapted to further analyse wellbore deposits.

MODE(S) FOR CARRYING OUT THE INVENTION

(I) ACOUSTIC SCALE/DEPOSITS SENSOR

20 The scale (or deposits) sensor consists of an ultrasonic piezoelectric transducer operating in a longitudinal mode coupled to a suitable metal horn. The resulting ultrasonic device is characterised by a sharp resonant frequency, which can be conveniently determined by the measurement of the admittance
25 (or impedance) spectrum of the device. The resonance frequency of the appropriate longitudinal mode is sensitive to any solid deposit that forms on the tip of the horn and the magnitude of the frequency shift is a measure of the mass loading. These ultrasonic transducers typically operate in the frequency range
30 10-100 kHz and can deliver high levels of acoustic power, typically in the range 1-500 W, when driven by a high input alternating voltage at its resonant frequency.

FIG. 1 shows schematics of several types of acoustic horn
35 attached to an ultrasonic transducer. The basic elements of the

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scale deposit sensor **10** are a transducer **11** made of piezoelectric material, a power supply with electrodes **12** to cause oscillations of the transducer, and a horn **13**. The horn is made of aluminum. The working surface of the transducer **131**, on which the deposition of the scale is sensed, is the tip of the horn. In a downhole and surface installations, the tip **131** (or **141**, **151**, and **161** for the embodiments of Figures 1B, 1C, and 1D respectively) will be exposed to wellbore/production fluids and accumulate deposits.

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The resonant frequency of the acoustic device operating in a longitudinal mode is determined by the size of the piezoelectric and the attached horn and the materials from which the piezoelectric and metal horn are constructed. The variants differ in their respective horn design. The horn **13** shown in FIG. 1A has a stepwise tapering. In FIG. 1B, the tapering is smooth with an exponentially reducing diameter of the horn **14**. The horn coupled to the ultrasonic piezoelectric transducer is made of aluminium. The resulting device has a sharp resonant frequency in air of 40 kHz nominally and the area of the horn tip was 0.2 cm². In FIG. 1C, the tapering is degenerated to a single step giving the horn **15** a pin-like shape. Other horn shapes can be envisaged, including the case where its thickness is very much less than the wavelength of sound and the horn is a thin layer of material that couples the ultrasonic transducer to the bore hole fluids and their deposits.

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Further indicated in FIG. 1 is the length of the horn as integer multiple N of half the wavelength ($\lambda/2$) of the acoustic wave generated by the transducer. FIG. 1D shows the case where the length of the horn **16** is very much less than $\lambda/2$ and the horn tip **161** has the same area as the ultrasonic transducer.

Table 1 shows the resonant frequency of the ultrasonic horns and the widths of the resonance at half peak height shown in FIG. 1A-C. The peak width of the resonance is typically 1-2% of the resonant frequency.

5

Table 1. Resonant frequencies in air of the ultrasonic transducers shown in FIG. 1A-C.

10

Transducer type in FIG. 1	Resonant frequency (kHz)	Width of resonance at half peak height (Hz)
A	19.86	21
B	39.04	52
C	54.63	96

FIG. 2 shows the resonant frequency of the acoustic sensor shown in FIG. 1B as measured by the real part of the admittance in Siemens (S). The resonant frequency of the ultrasonic transducer is modified by the nature of the fluid in which it is immersed. FIG. 2 compares the resonant frequency of the ultrasonic transducer immersed in air, water and kerosene. The resonance frequency of the transducer decreases when the metal horn is immersed in a denser fluid and the resonance broadens with more viscous fluids. The fine structure (shown in FIG. 2B) on the admittance spectra measured when the transducer is immersed in water and kerosene at ambient pressure is caused by the attachment of small air bubbles to the horn.

25

FIG. 3 shows the shift in the resonant frequency of a transducer and metal horn with thickness of attached scale when the horn is immersed in water in a pressure vessel at a hydrostatic pressure of 4000 psi (270 bar). The resonant frequency of the 20 kHz

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transducer shifts by 85 Hz per millimetre of scale of density 4.50 g/cm³.

Further measurements show the variation of the shift in the
5 resonance frequency of a 40 kHz transducer as a function of
scale thickness in water at ambient pressure for two scale types
with densities of 2.75 and 4.50 g/cm³. The resonant frequency of
the transducer decreases by 774 Hz per millimetre of scale of
density $\rho=2.75$ g/cm³ and 966 Hz per millimetre of scale of
10 density $\rho=4.50$ g/cm³.

The accumulation of inorganic scale can also be detected by a
shift in the resonant frequency of a transducer when the horn is
immersed in a liquid hydrocarbon. When comparing the admittance
15 spectra of a 40 kHz transducer and horn immersed in kerosene at
ambient pressure with and without inorganic scale attached, it
was found that the shift in the resonant frequency of the
transducer is 1317 Hz per millimetre of scale of density $\rho=4.50$
g/cm³ in kerosene at ambient pressure.

20

The resonant frequency of an ultrasonic transducer and horn also
decreases when organic deposits, such as wax, form on the tip of
the horn. FIG. 4 shows the admittance spectra of a 40 kHz
ultrasonic transducer and metal horn immersed in water at
25 ambient pressure with wax of various thicknesses attached to the
tip of the horn. The resonant frequency of the transducer
decreases by 180 Hz per millimetre of wax of density 0.79 g/cm³
when the horn is immersed in water at ambient pressure.

30 (II) ACOUSTIC SCALE/DEPOSITS CLEANING

The inorganic and organic deposits that accumulate on the tip of
the horn can be removed by applying a high alternating voltage
to the transducer. The strain produced in the transducer and the
35 attached horn breaks the bond between the horn tip and the

The electrical power that is required by the transducer to remove the scale from the tip of the horn can be determined from the input voltage and current. The frequency of the input
25 voltage and current is 19.84 kHz, which compares to a value of 19.81 kHz obtained from the admittance spectrum of the cleaned horn. The scale, which consisted of a deposit with a density of 4.50 g/cm³ and a thickness of 1.47 mm, was removed from the metal horn at a hydrostatic pressure of 136 bar (2000 psi). FIG. 6
30 shows the input power waveform supplied to the transducer during the cleaning of the scale. The modulus of the time-averaged input electrical power of the waveform shown in FIG. 6 is 20.4 W.

In FIG. 7 reference is made to an "intelligent" completion system deployed to control the flow of wellbore fluid into a production pipe.

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FIG. 7 shows a schematic of part of an intelligent completion system. An intelligent completion allows active control of downhole processes such as flow rate measurements and control. A wellbore 70 is shown with a casing 701 installed. At certain locations the casing 701 is perforated by holes 702 to allow wellbore fluid to enter the wellbore. Installed within the wellbore is a production pipe 71 with a slotted section 711. Wellbore fluid enters the production pipe via the slotted section 711. Mounted within the production pipe is a sliding sleeve 712. The sliding sleeve 712 controls the flow of reservoir fluids into the production tubing from a particular section of the well. The flow rate, pressure and temperature of the production fluids are measured by a sensor sub 713 near the slotted section 711 into the tubing. The sliding sleeve 712 is operated by a downhole electrical motor 714 that is powered by means of an electrical cable 721 from the surface 72.

One problem associated with the use of a sliding sleeve is the formation of wellbore deposits, such as inorganic scale or wax, on the sleeve or its track. It is common practice to design the completion hardware such that the electric motor 714 is sufficiently powerful to remove small amounts of scale when the sleeve is moved. However, attempting to remove scale or other deposits by scraping with the sleeve 712 may result in damage to the track and possible jamming. The location of an acoustic scale sensor 715 close to the sliding sleeve 712 will enable the accumulation of deposits on completion hardware to be assessed quantitatively through control equipment 722 located at the surface. Transfer of energy and data signal between control equipment 722 and the sensor 715 is done via wiring 716 run with the production tubing. If scale accumulation on the sleeve is considered to be above a level at which it can be safely operated, then an external scale removal process may be required (e.g., application of a scale dissolver solution).

Alternatively, the control equipment 722 could be used to activate the sleeve periodically or responsive to a threshold amount of deposit as measured by the scale sensor 715. In yet another alternative the control equipment 722 could at least partly be incorporated into the downhole installation. By thus providing a direct feedback control between sleeve and deposit monitor 715, the amount of intervention from the surface can be reduced.

According to the invention, acoustic cleaning of scale and other deposits is provided. The ultrasonic transducer and associated horn can be used to remove scale and other deposits (wax, asphaltene, etc.) from critical components that are used in measurement devices exposed to wellbore/production fluids in the wellbore or on the surface. The components can be part of measurement systems that are either permanently installed in producing hydrocarbon wells or surface facilities or temporarily exposed to the fluids produced by the hydrocarbon well, e.g., on a wireline-deployable tool. Critical components exposed to wellbore fluids that may require cleaning include separation membranes, optical windows and electrical contacts such as electrodes.

FIG. 8 refers to a venturi-type flowmeter having a gamma-ray sensor in its constriction section.

It shows a schematic of a gradio-venturi tube 81 located in the tubing 80 of a producing hydrocarbon well. The section of tubing 80 can be located either in a well or on surface facilities. Located within the constriction formed by the venturi 81 is a gamma ray sensor 82. Details of those known components of a gradio-venturi can be found for example in US Patent No. 5,591,922. The gamma ray sensor, which consists of a gamma ray source 821 (frequently a dual energy source) and a gamma ray detector 822, such as a photomultiplier tube. The

gamma rays enter and leave the tube by means of nuclear windows 823 made of a material such as boron carbide. Gamma-ray devices as described above are known as such and described for example in the U.K. Patent Application No. 9919271.8.

5

A significant problem faced by the gamma ray density measurement is the accumulation of inorganic or organic scales on the nuclear windows 823. For example, the accumulation of small amounts of barium sulphate (barite) scale may result in a serious overestimate of the density of the production fluids. Similarly, the accumulation of radioactive scales on the nuclear windows may give rise to erroneous measurements. The accumulation of organic scales, such as asphaltenes that may contain elements with of high atomic number, can also corrupt the density measurement.

15

One solution to the problem of deposits accumulation on the nuclear windows 823 is to incorporate them into a high power ultrasonic transducer and horn as is the subject of the present invention (see FIG. 1 above). FIG. 8 shows the two windows located in a hollow horn 824 and transducer 825; the windows 823 are cleaned by operating the transducer in its high power mode. The accumulation of deposits on the windows can be measured by a shift in the resonance frequency of the transducer and horn, as described above.

20

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The gradio-venturi tube of the type above can be located either on the surface or downhole, e.g., as part of an intelligent completion system.

30

FIG. 9 shows further examples of the use of an ultrasonic transducer and horn to clean measurement devices that may be deployed in a producing hydrocarbon well or at surface installation monitoring the flow of hydrocarbon from the well.

35

FIG. 9A shows a schematic of an optical window 931 located at the tip of a horn 93 attached to an ultrasonic transducer 91. The optical window 931, which can be made of a suitably resistant material such as diamond or sapphire, can be connected to a source and detector using an optical fibre 95 or other optical conduit such as a light pipe. The optical transmission of the window can be maintained by removing deposits of organic and inorganic scales with ultrasonic cleaning. The accumulation of deposits on the optical window can be determined by either the decreased transmissivity of the window or the change in the admittance spectrum of the transducer 91 and horn 93 assembly. The optical windows can be located either in a producing oil well, on a permanent or quasi-permanent basis, or on the surface facilities. The acoustic cleaning of optical windows can also be applied to wireline logging tools, such as the optical windows used in the Optical Fluid Analyser in Schlumberger's Modular Dynamics Formation Tester tool (described in U.S. Patent No. 4,994,671) or the windows used in the optical probes to monitor multiphase production from hydrocarbon wells, as described in U.S. Patent No. 5,831,743.

FIG. 9B shows a schematic of an ultrasonic transducer 91 and horn 94 used to clean the membrane 961 of an ion selective electrode 96 that could be used to measure the activity of an ionic species in the water produced from a hydrocarbon well. The performance of the membrane 961 is maintained by the cleaning action of the ultrasonic transducer 91 and horn 94, which are in close proximity to the membrane. The ultrasonic cleaning technique can be used to maintain the permeability of membranes used to separate various components from the fluids produced from hydrocarbon wells, e.g., gas extraction membranes, oil-water separation membranes. Note that a separation membrane and electrode can also be incorporated into the horn coupled to a transducer. The separation membranes can be similarly located in

a producing wellbore or in the surface facilities of a producing well.

According to the invention, a method for the identification of scale type is provided. The resonant frequency of the transducer and horn responds to the mass of the attached deposits and it may not be possible to identify the type of scale deposit in the absence of other measurements. One of a variety of measurements could be used to identify the type of scale deposit accumulated on the acoustic horn and thus enable acoustic scale sensor to measure the thickness of the deposit. Two examples are give. Firstly, a spectroscopic measurement could be employed, using an optical widow of the design shown in FIG. 9A. The scale type can identified by a total internal reflection spectroscopic technique, such as infrared spectroscopy, or Raman spectroscopy, which, as reflection and scattering techniques, are insensitive to the thickness of the scale layer. A second possible technique is to use a second acoustic sensor, embedded in the acoustic horn, to measure the acoustic transit time through the scale deposit.

FIG. 10 shows a schematic of the acoustic sensor used to measure the acoustic transit time ΔT_t through the scale film. This acoustic sensor could be used either downhole or above ground on the surface facilities. Pulsed ultrasound is emitted from an emitting transducer 981 and the reflections are collected by a second receiving transducer 982. The acoustic impedance Z of the scale layer 99 can be estimated by the measured values of the mass W of scale attached to the acoustic horn 97 and ΔT_t . The thickness of scale h attached to the horn is related to W by

$$[1] \quad h = \frac{W}{\rho_s A}$$

where ρ_s is the density of the scale and A is the area of the tip of the horn. The thickness h is related to ΔT_t by

$$[2] \quad h = \frac{\Delta T_t V}{2} ,$$

5

where V is the velocity of sound in the scale layer. The combination of eqn.[1] and [2] gives

$$[3] \quad Z = \rho_s V = \frac{2W}{\Delta T_t A} .$$

10

The scale type can be discriminated by the measured value of Z. Table 4 shows the values of the acoustic impedance Z as a function of scale type. When Z is identified the thickness h of the scale deposit can be calculated using eqns.[1] or [2] using the known values of V and ρ_s .

15

Table 4. Values of the acoustic impedance Z for various inorganic scales.

20

Scale type	Acoustic impedance Z (kg/m ² s × 10 ⁻⁶)
calcite	17.6
anhydrite	18.0
celestite	19.1
barite	19.9

According to the invention monitoring scale/deposits removal techniques are provided. The acoustic scale sensor can be used to evaluate the efficiency of an external scale removal treatment process, such as a scale dissolver solution or a physical scale removal technique. The scale removal treatment can be monitored in real time using the change in the resonant frequency of the transducer and horn. The acoustic scale monitor

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can therefore be used as part of a scale maintenance service that monitors scale accumulation and evaluates the cleaning/removal process. The maintenance service can be applied to the accumulation of scale both in a producing wellbore or in
5 the surface equipment.

According to the invention, fluid composition and pressure effects can be determined. The resonant frequency of the ultrasonic transducer and horn with no deposits attached depends
10 on the composition of the fluid with which it is in contact and its hydrostatic pressure. A change in the composition of the produced fluid or its hydrostatic pressure may therefore obscure the change in resonant frequency due to the accumulation of inorganic or organic deposits. A change in resonant frequency
15 due to a change in fluid properties can be measured using a second matched transducer and horn, which is in close proximity to the scale detector. The second transducer is cleaned frequently to ensure that the horn is always free from inorganic and organic scales and that the changes in its resonant
20 frequency are solely caused by changes in fluid composition and pressure.

Surface Modification of Acoustic Horn. An important aspect of a scale/deposits sensor permanently installed in a producing
25 hydrocarbon well or in the surface facilities is that the rate of accumulation of deposits must be the same as that of the region of the wellbore it is monitoring. The composition and morphology of the surface of the tip of the horn should be such as to give the same rate of scale accumulation as the solid
30 surfaces in the close environs of the sensor. The surface of the horn tip should be suitably controlled by the choice of material and/or coating. The material and coating used to fabricate the horn should be able to withstand repeated sonication.

Size of Transducer and Horn. The size of an ultrasonic transducer and horn may be a critical issue for the permanent placement of such a device for scale/deposits monitoring. The size of the transducer and horn are largely determined by the
5 desired frequency of operation and the materials use to them. High power ultrasonic transducers and horns in the size range 5-6 cm, which operate in the frequency range 89-113 kHz, have been reported by Lal and White. See, Lal, A. and White, R.M.,
10 "Silicon microfabricated horns for power ultrasonics", *Sensors and Actuators*, **A54**, 542-546 (1996). The acoustic horns were microfabricated from silicon wafers.

While preferred embodiments of the invention have been described, the descriptions and examples are merely illustrative
15 and are not intended to limit the present invention.

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CLAIMS

What is claimed is:

- 5 1. A deposit monitoring apparatus located in a hydrocarbon wellbore comprising:
 an acoustic device adapted to operate in a resonance mode including a monitoring surface directly exposed to fluids in a hydrocarbon wellbore, wherein the deposition of
10 material on the monitoring surface is monitored by measuring a change in resonance frequency of the acoustic device; and
 a power supply adapted to supply said monitor with electrical energy.
15 2. The apparatus of claim 1, wherein the acoustic device is mounted either permanently or quasi-permanently in the wellbore.
20 3. The apparatus of claim 1, wherein the acoustic device operates in a longitudinal mode.
 4. The apparatus of claim 3, wherein the acoustic device further comprises a transducer, and a focussing element coupled
25 to the transducer.
 5. The apparatus of claim 4, wherein the focussing element is an acoustic horn.
30 6. The apparatus of claim 1, wherein the resonance frequency of the acoustic device is in the range of 10 kHz to 150 kHz.

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7. The apparatus of claim 6 wherein the resonance frequency of the acoustic device is in the range of 50 kHz to 100 kHz.

5 8. The apparatus of claim 1, wherein the monitoring surface is located on or near one of the following devices switches, valves, sleeves, mandrels, downhole separators and sensors located in the wellbore.

10 9. The apparatus of claim 1 further comprising a deposit removal system adapted to at least partially remove the deposition from the monitoring surface, the deposit removal system being in a control loop with said deposit monitor.

15 10. The apparatus of claim 9, wherein the deposit removal system includes a deposition inhibiting or removing chemical agent.

20 11. The apparatus of claim 9, wherein the deposit removal system uses the acoustic device to exert a physical force onto the deposited material.

25 12. The apparatus of claim 9, wherein the deposition removal system is near a sensor having a surface exposed to the fluids and the deposition removal system is adapted to remove deposits from said exposed surface.

30 13. The apparatus of claim 12, wherein the sensor is selected from a group comprising optical sensors, electro-chemical sensors, or acoustic sensors.

14. The apparatus of claim 11, wherein the exposed sensor surface is selected from a group comprising optical windows, membranes, or sensitive areas of acoustic sensors.

25. The apparatus of claim 18, wherein the sensor is selected from a group comprising optical sensors, electro-chemical sensors, or acoustic sensors.

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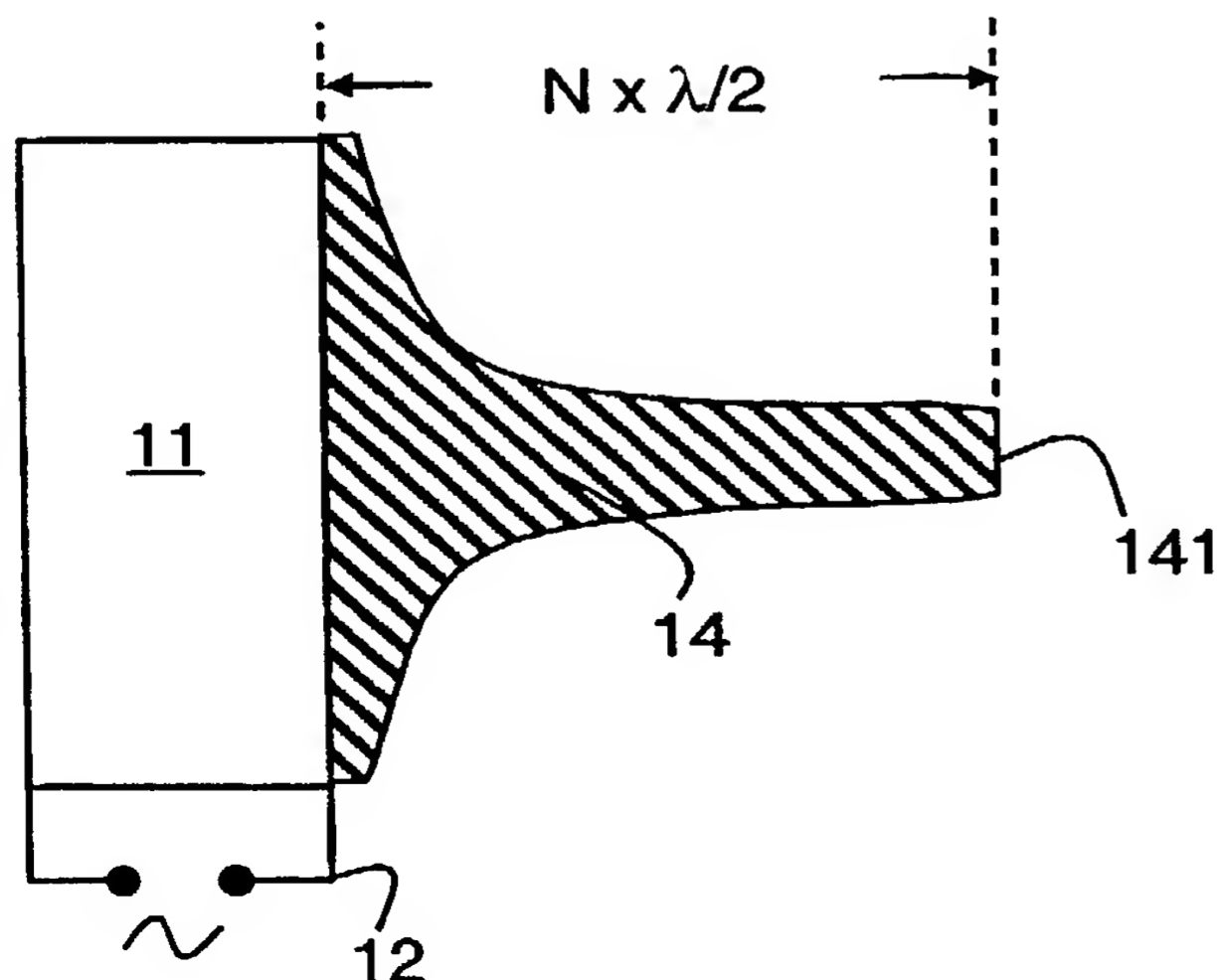
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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette

(54) Title: DOWNHOLE DEPOSITION MONITORING SYSTEM



(57) Abstract: Described is a downhole apparatus for detecting and removing deposits from a surface exposed to wellbore fluids. The apparatus can monitor the rate of deposition and subsequently remove the deposited material. The combination of detection apparatus and removal apparatus provides a downhole instrument with self-cleaning operation mode.

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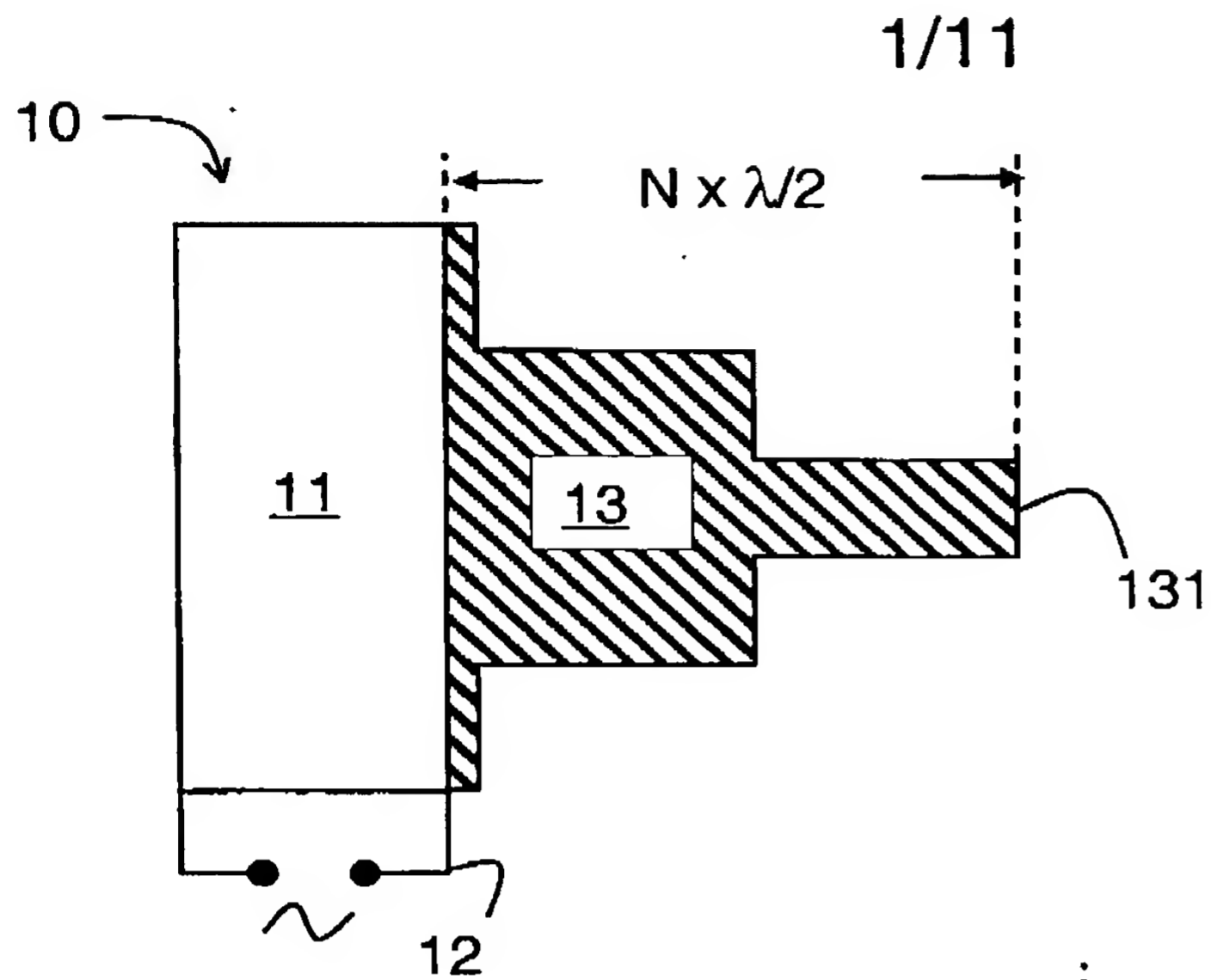


FIG. 1A

FIG. 1B

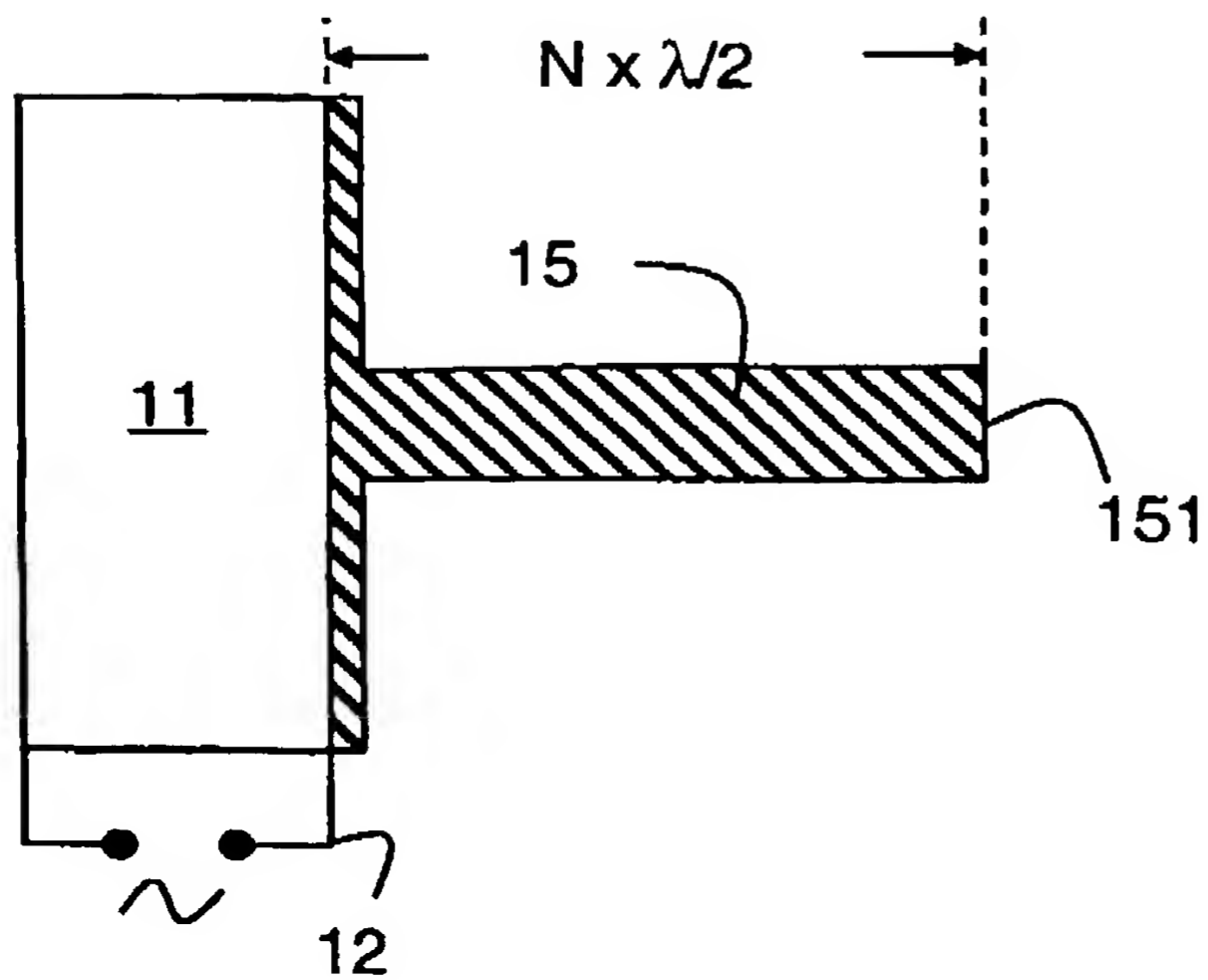
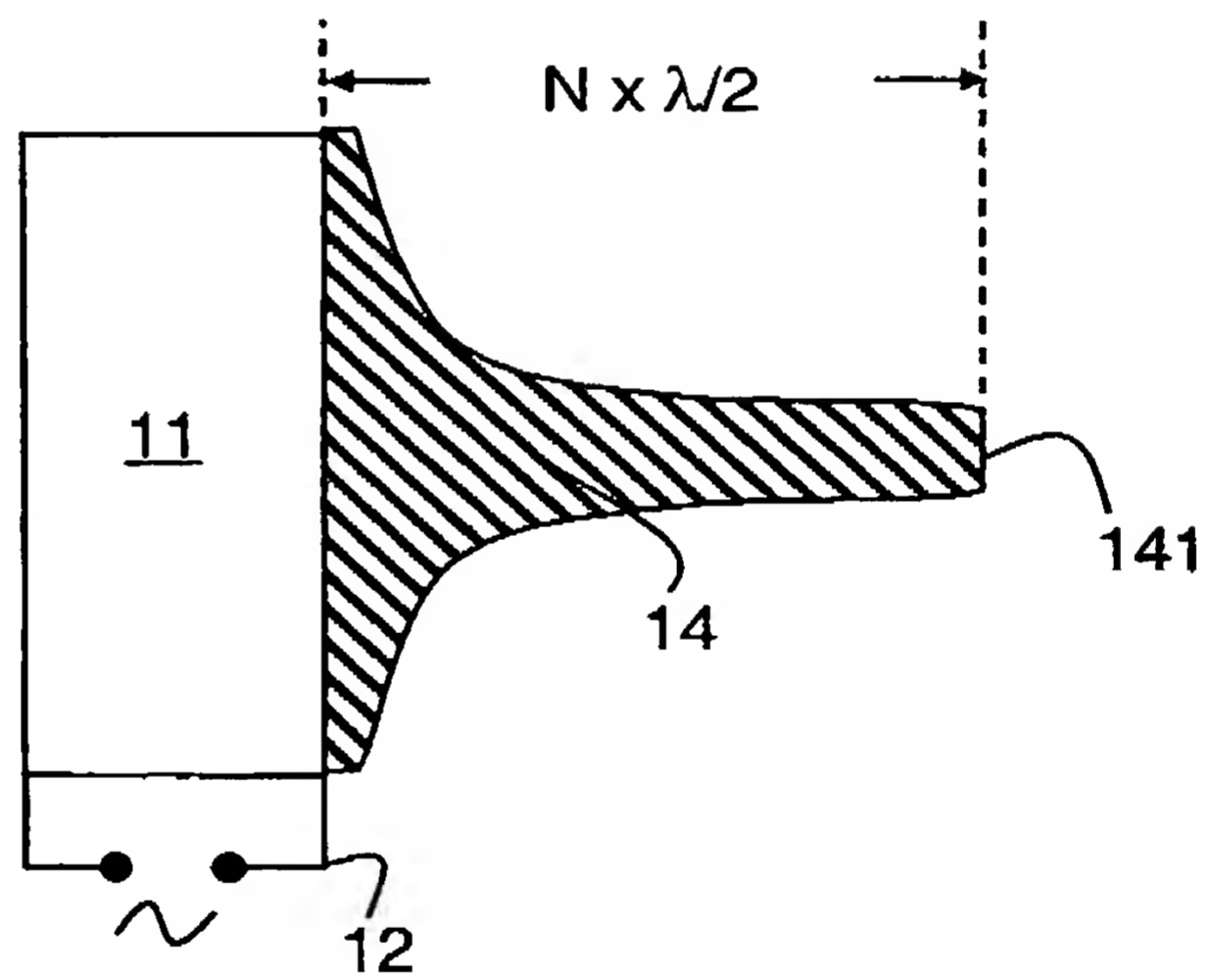


FIG. 1C

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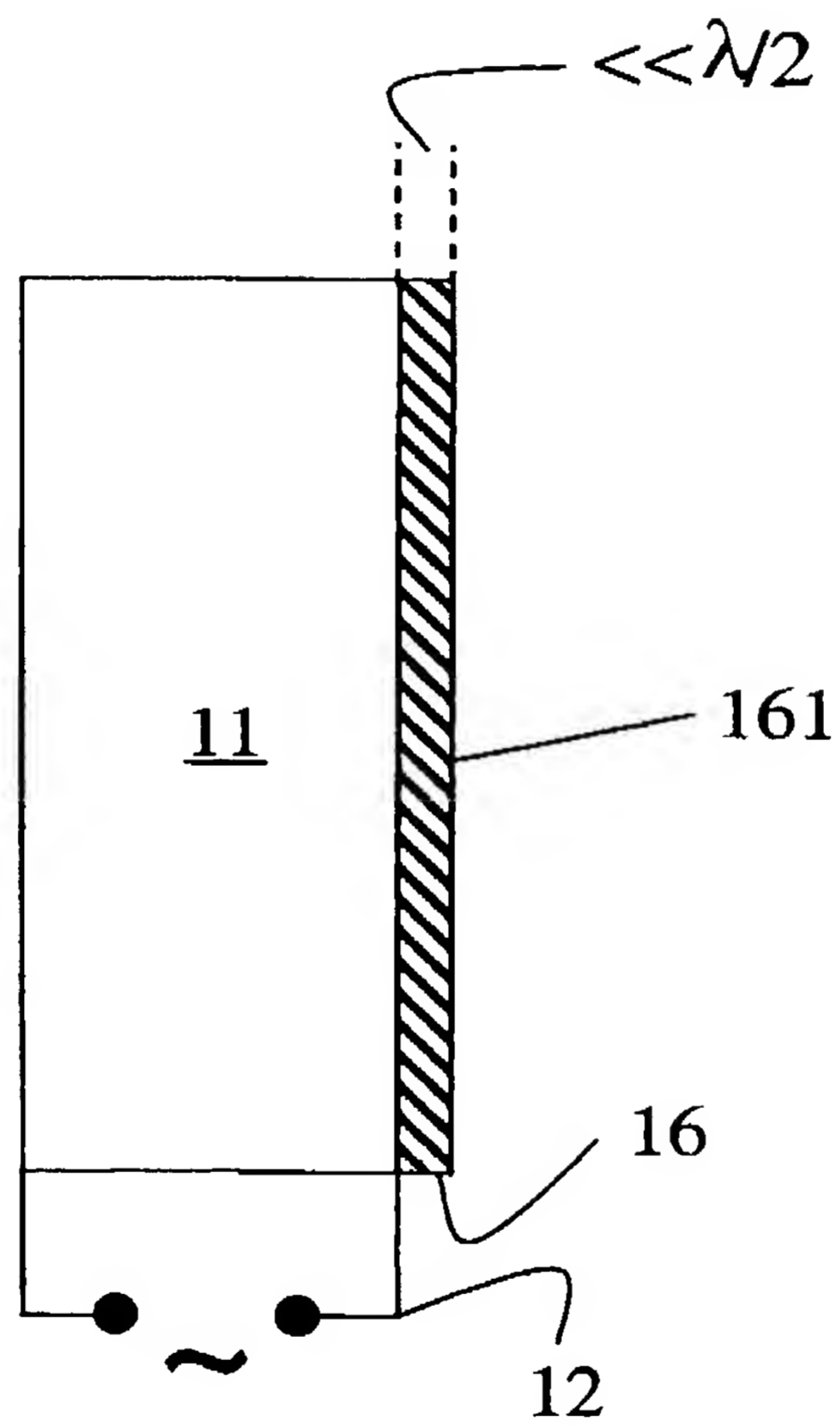
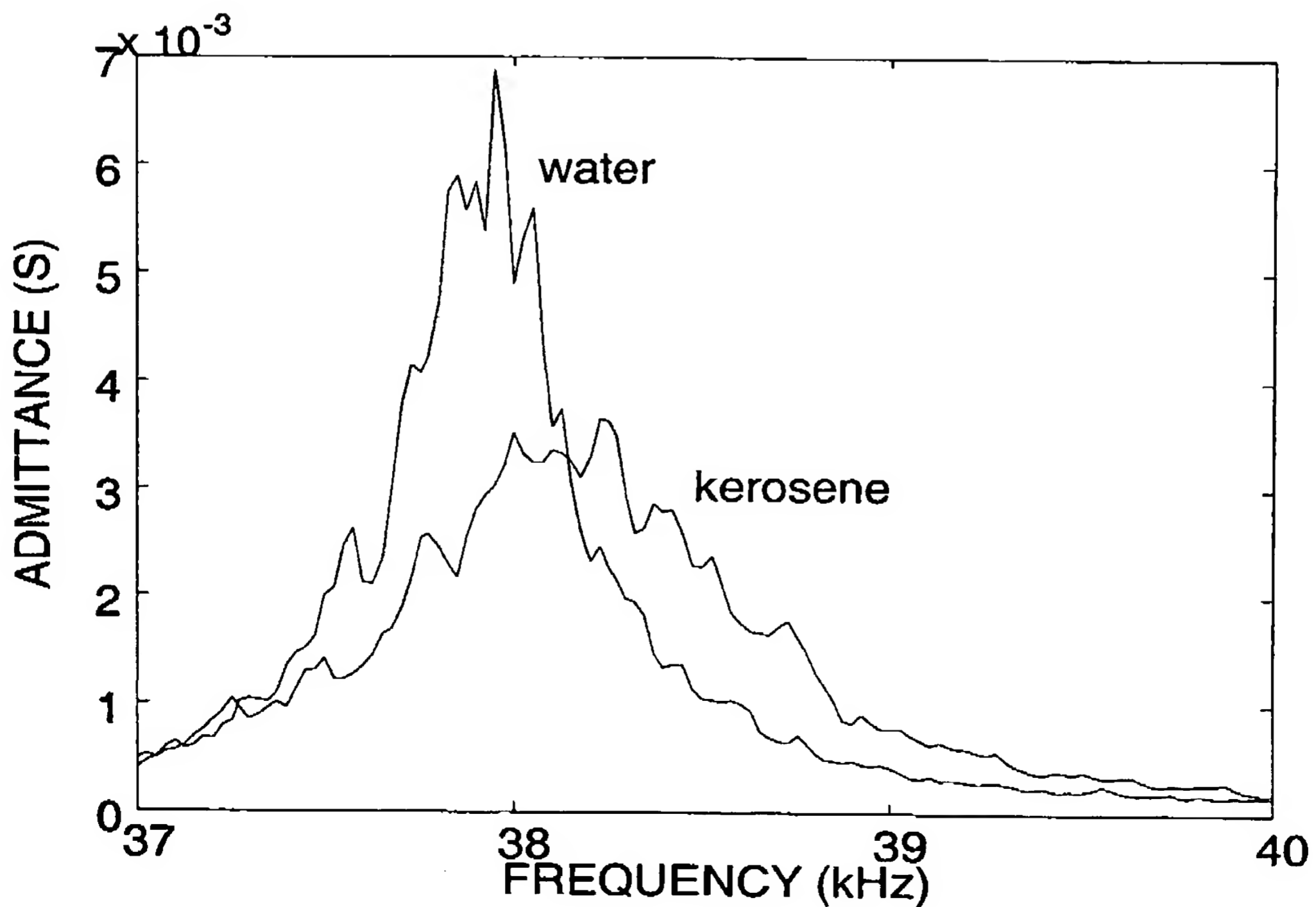
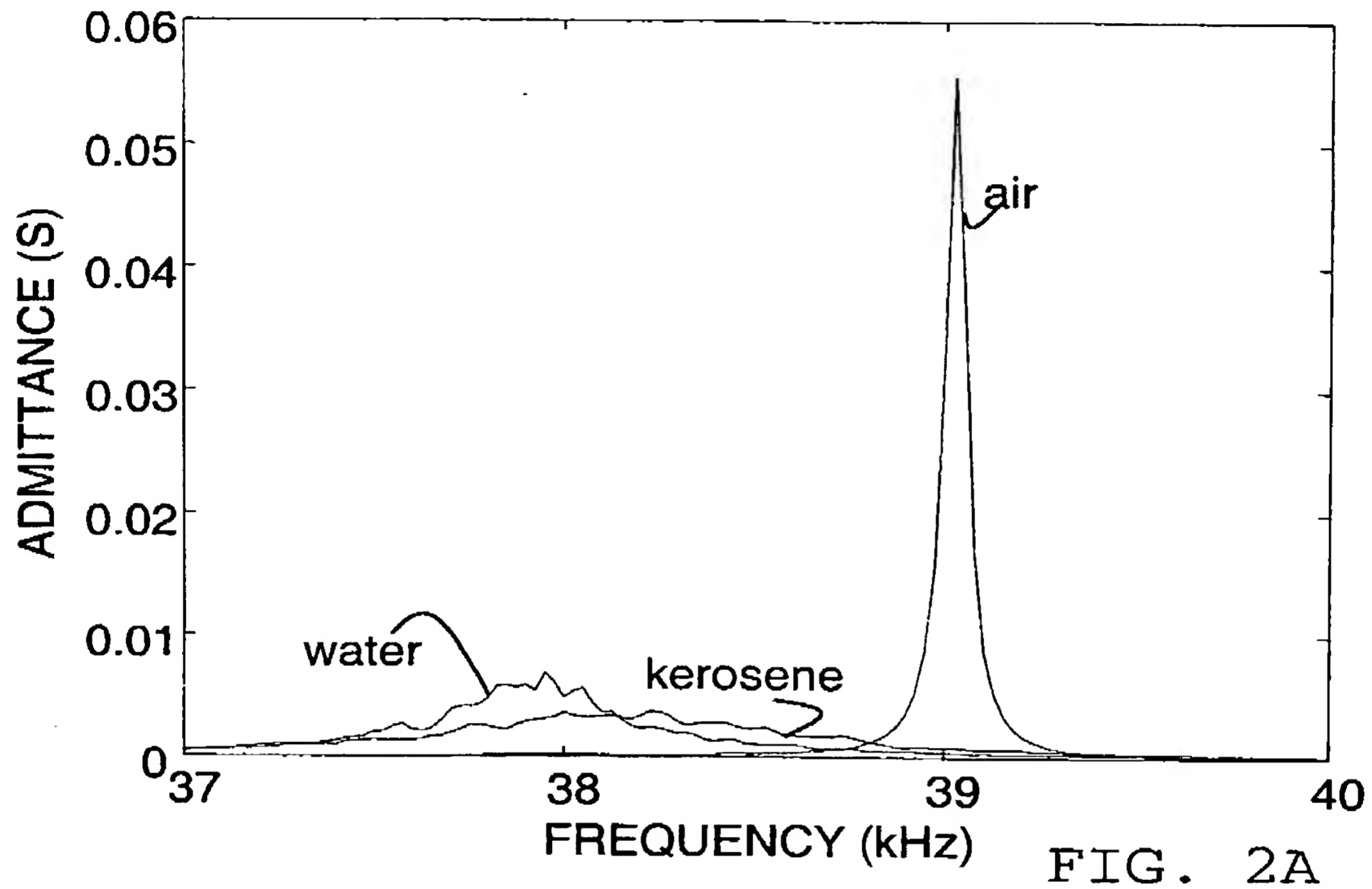


FIG. 1D

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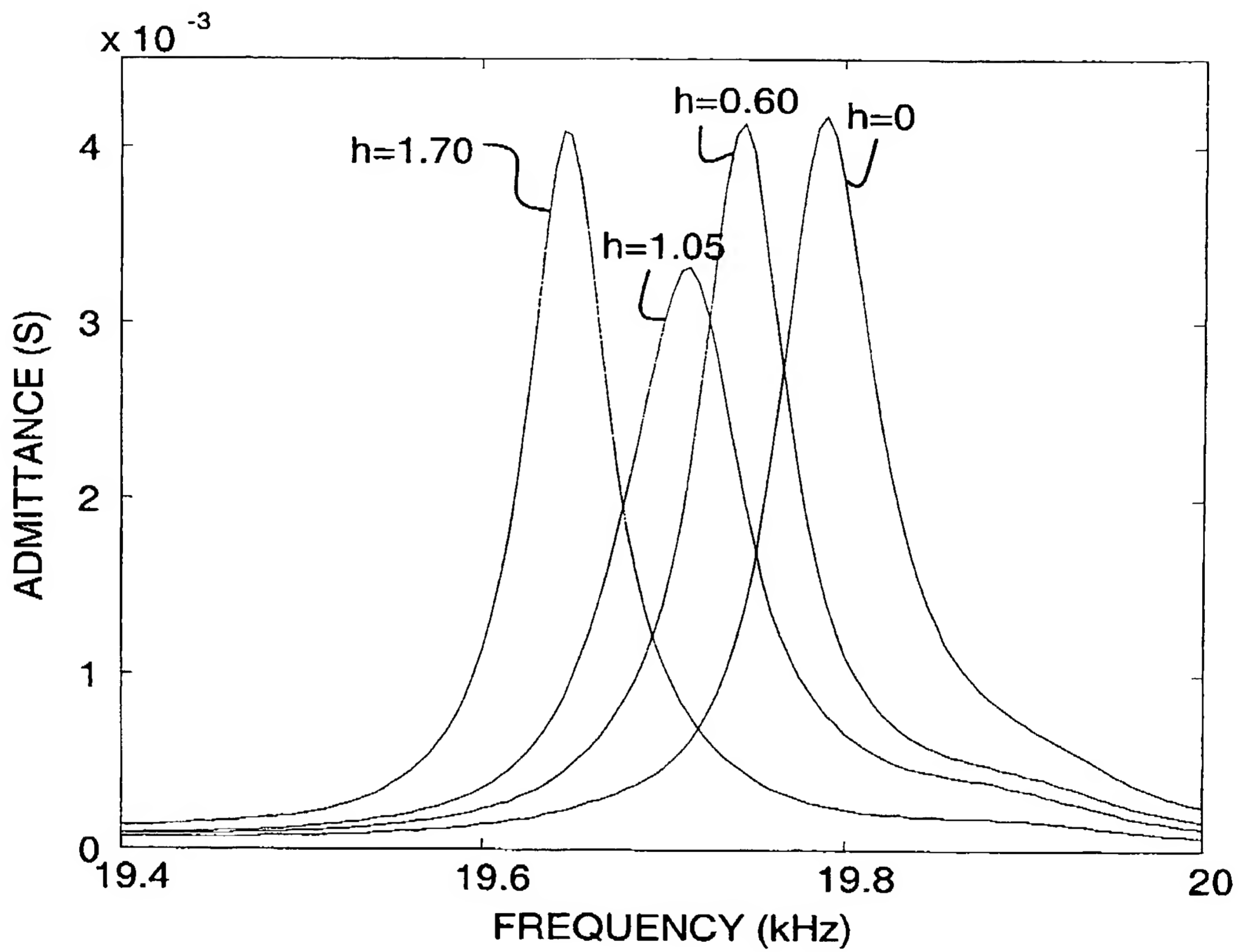


FIG. 3

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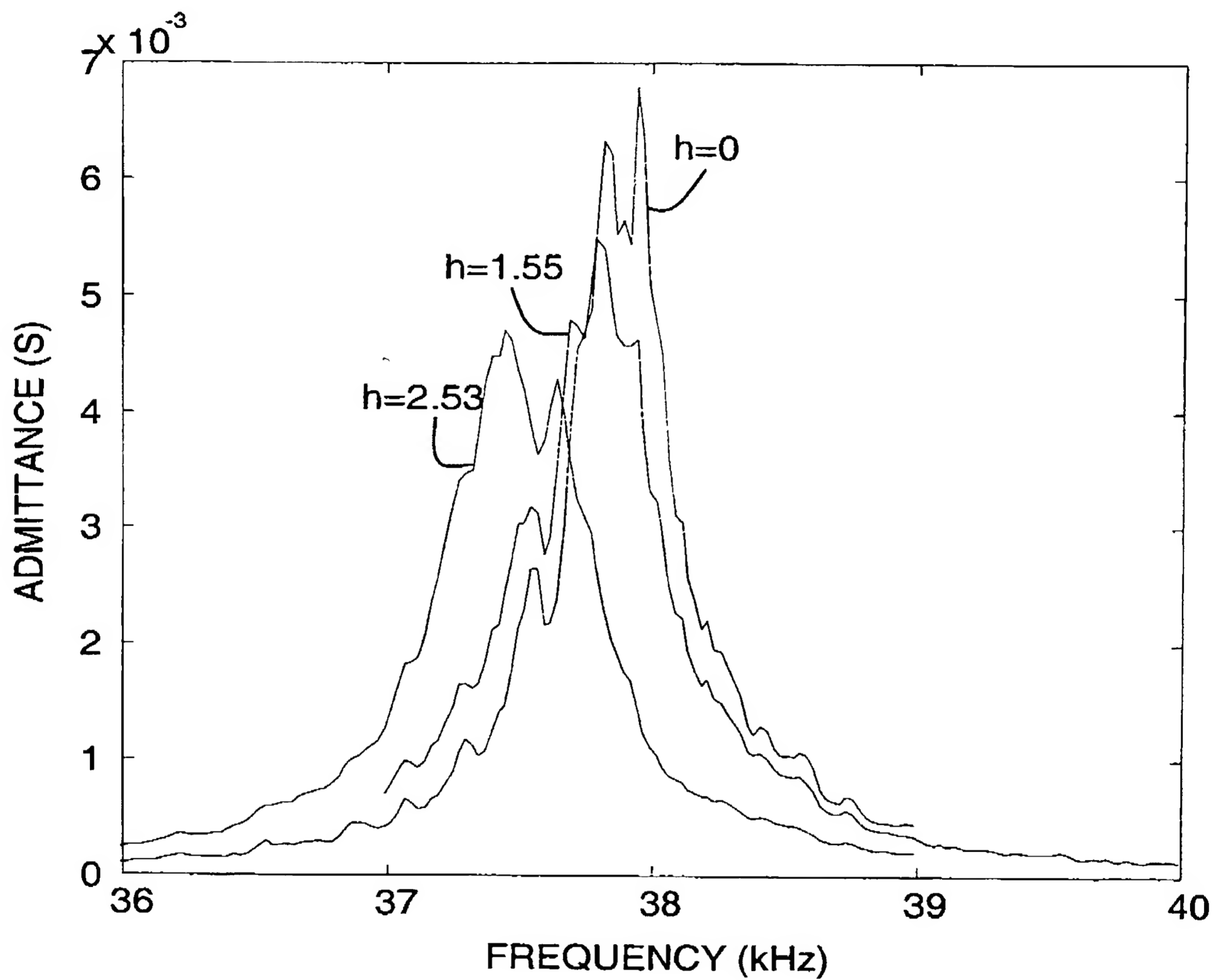


FIG. 4

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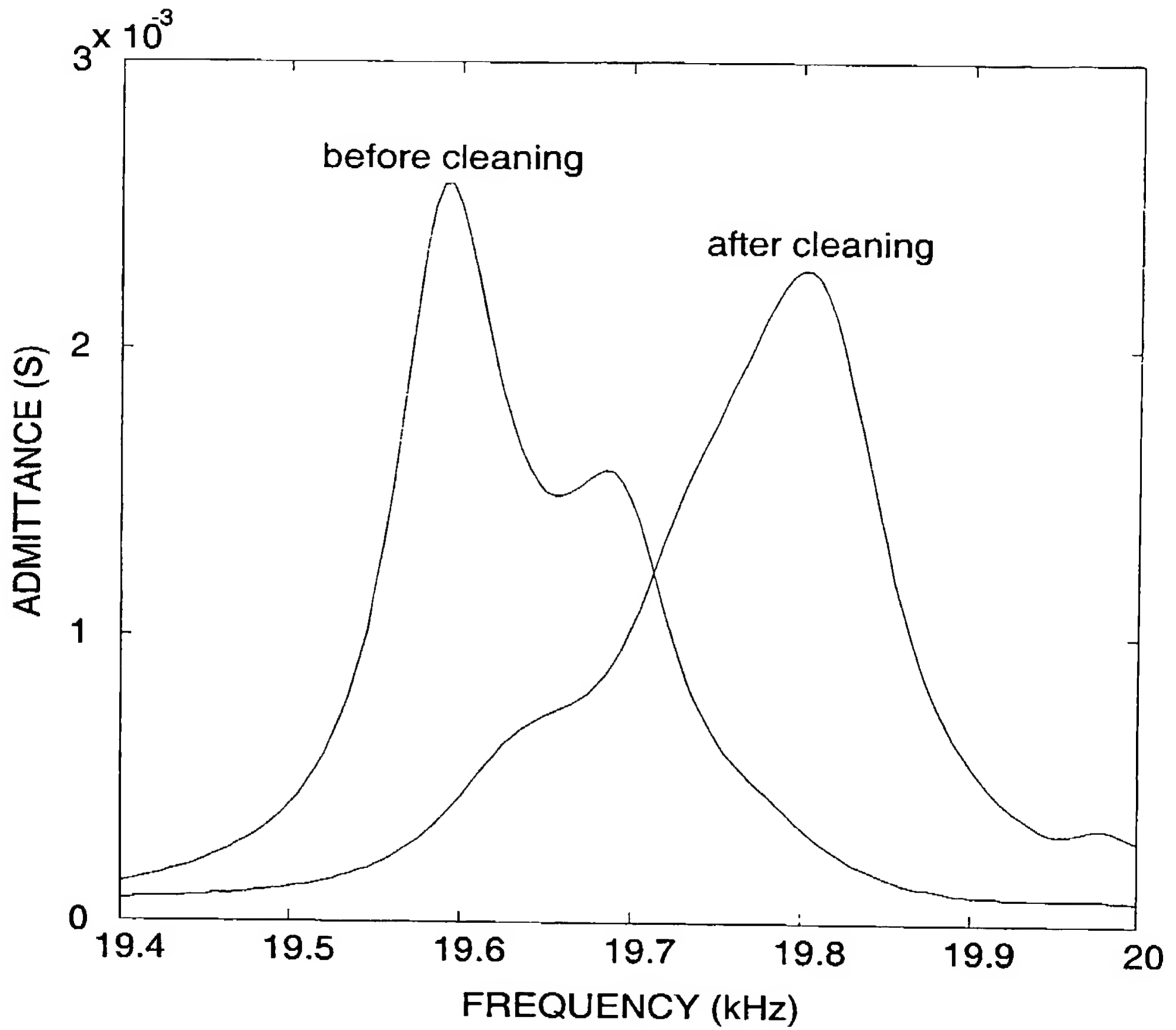


FIG. 5

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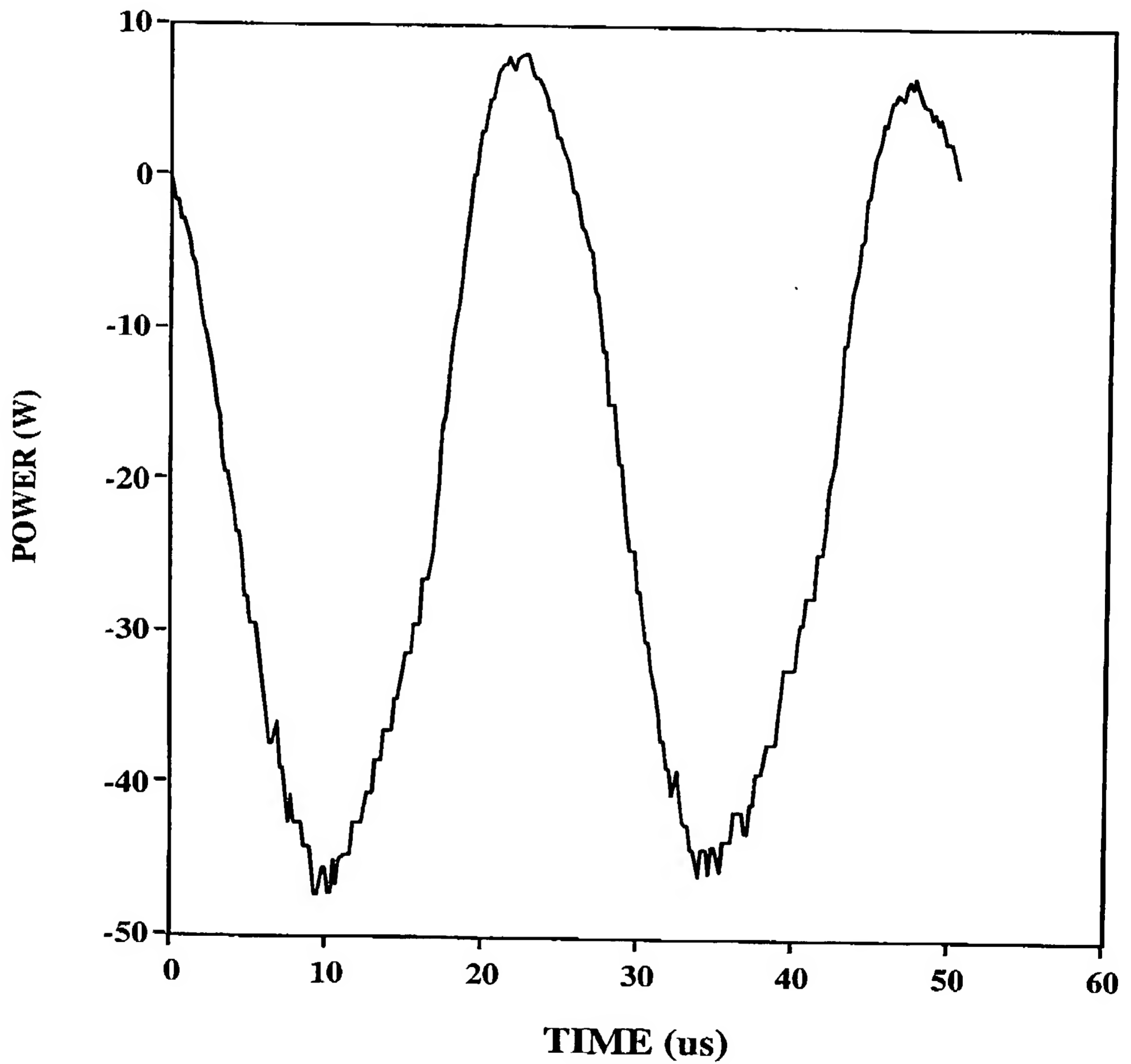


FIG. 6

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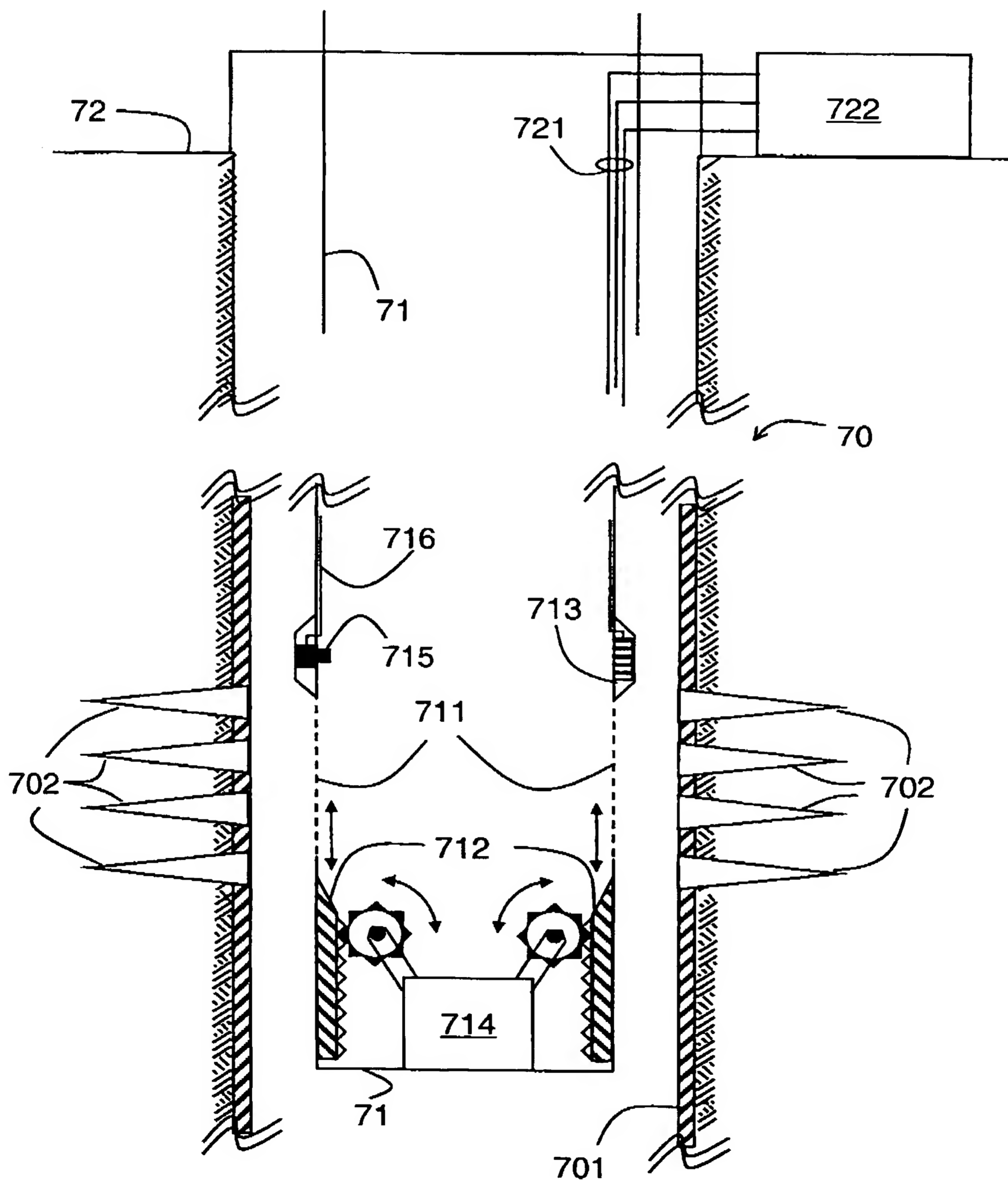


FIG. 7

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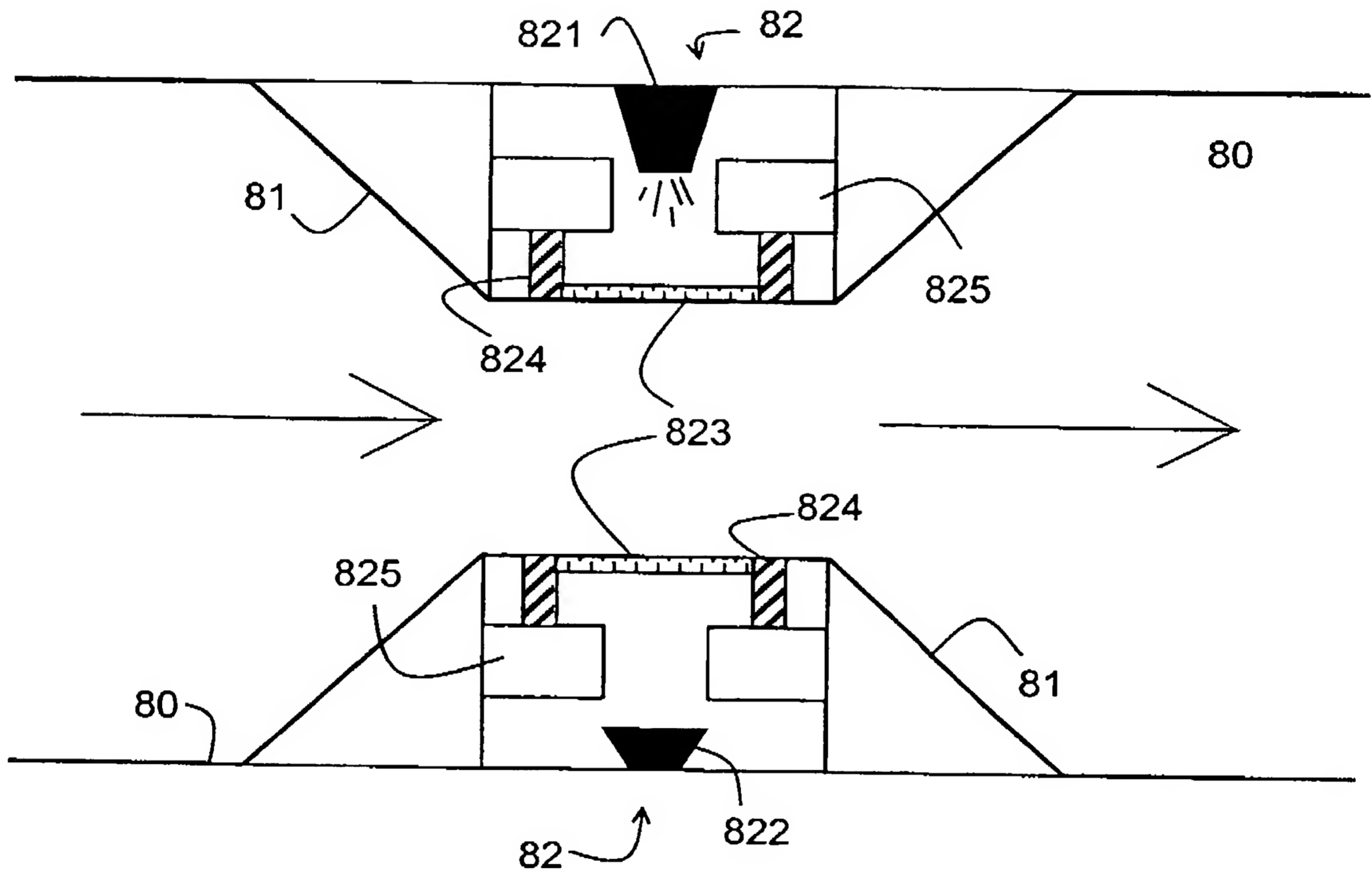


FIG. 8

10/11

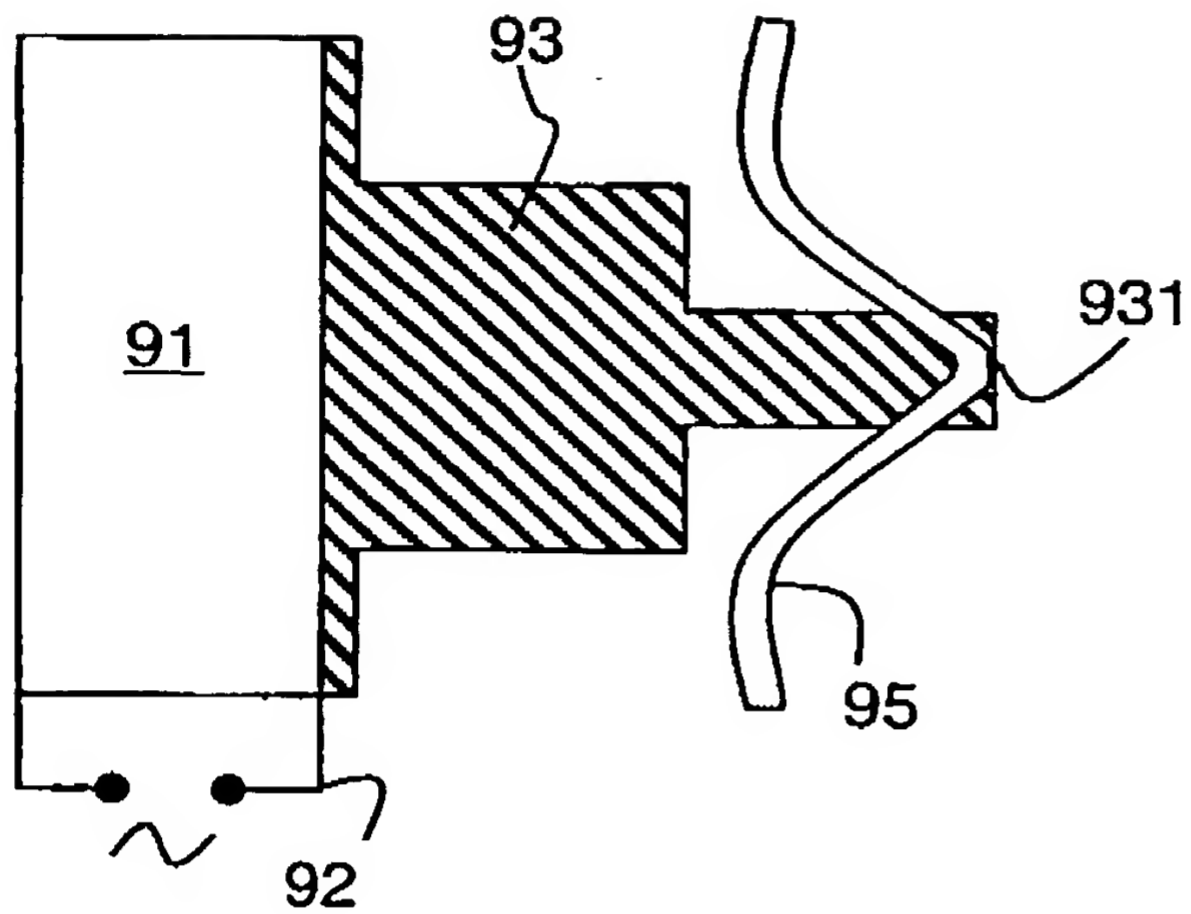


FIG. 9A

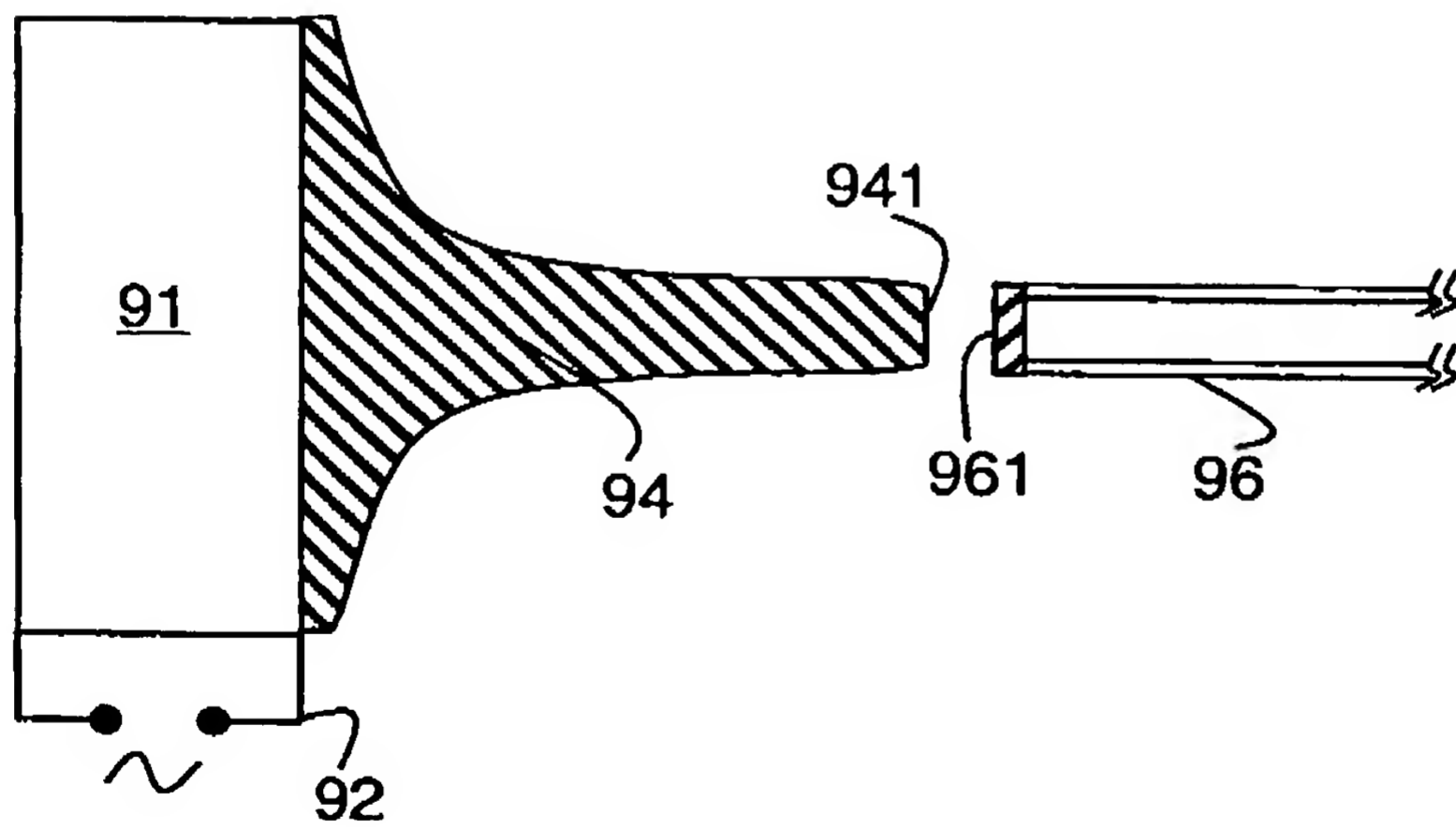


FIG. 9B

11/11

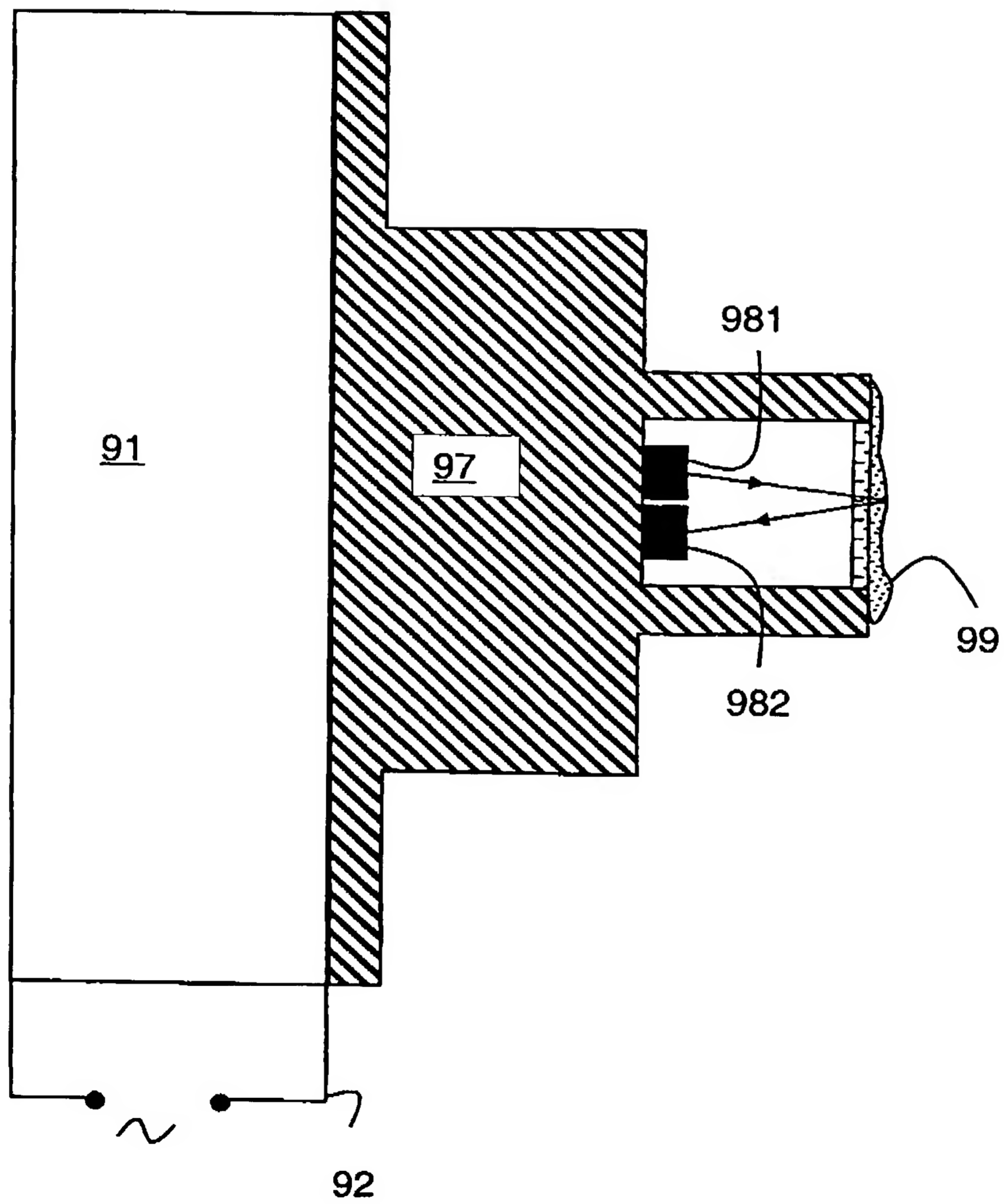


FIG. 10

DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY

As a below named inventor, I/We hereby declare that:

My/Our residence, post office address(s) and citizenship(s) are as stated below next to my/our name(s), and

I/We believe I/We am/are the original, first and sole inventor of the subject matter which is claimed (if only one name is listed below) or an original and first inventor of at least some of the subject matter which is claimed (if plural names are listed below) and for which a patent is sought on the invention entitled

DOWNHOLE DEPOSITION MONITORING SYSTEM

the specification of which

☐ is attached hereto.

☒ was filed on **26 October 2000**

as PCT International Application No. **PCT/GB00/04128**

and was amended on _____ (if applicable).

I/We hereby state that I/we have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I/We acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

Prior Foreign Application(s)

I/We hereby claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Country	Application No.	Filed (d/m/y)	Issued (d/m/y)	Priority Claimed
Great Britain	9925373.4	(27.10.99) 27 October 1999		Y <input checked="" type="checkbox"/> N <input type="checkbox"/>
				Y <input type="checkbox"/> N <input type="checkbox"/>

Prior United States Applications

I/We hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I/We acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Section 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial No.	Filing Date (d/m/y)	Status (Patented, Pending, Abandoned)

And, I/We hereby appoint, both jointly and severally, as my attorney(s) and/or agent(s) with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith the following attorney(s) and agent(s), their registration numbers being listed after their names.

John J. Ryberg, 31,134; William B. Batzer, 37,088; William L. Wang, 39,871; and Jody Lynn DeStefanis, 44,653

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I hereby declare (if sole inventor) or each of us hereby declares (if joint inventors) that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

SOLE OR FIRST INVENTOR

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